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Cincinnati, Ohio

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The disposal of human excreta in early days was comparatively simple, and is still so in some of the rural sections, the chief development being the improvement of the privy. With increasing population in communities came the serious problems of public sanitation, which were not relieved materially until public water supplies and water-borne sewerage became established. Today, the conveniences of modern plumbing are demanded, not only in built-up communities where public water and sewerage systems are provided, but in rural and semi-rural areas as well. The availability of such services, and of electricity and modern transportation, together with the desire of many people for uncrowded living, is profoundly affecting the pattern of development of the modern American city, with consequent residential development in outlying fringe areas, where community sewerage systems often cannot be provided economically. Under these present circumstances, the individual home sewage disposal system is an important segment of American sewerage practice.

Some 17,000,000 persons are served by individual home sewage disposal systems in this country, as compared with about 47,000,000 persons served by municipal sewage treatment, of which some 22,000,000 are served by treatment processes comparable to that furnished by the home septic tank-soil absorption system. In recent F.H.A.-involved residential building, 40 per

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cent of the residences being built depend on individual home sewage disposal systems. In terms of number of plants, 4,400,000 individual home sewage disposal systems, as against 5,700 municipal treatment plants, is of consequence to administrative authorities in volume of inquiries and complaints. Only 40 per cent of the installations in use have been put in under organized control, and, until recently, little attention was given to factual investigation of their behavior. This, of course, is amply reflected in the difficulties found in this field today; but it is but part of the story. The other is the weakness on the operating side. Many householders have not been aware of their servicing responsibilities; some have been "burned" in their experience with servicemen. In either case there is the tendency to let servicing go until the system plugs. Therefore, technical improvements will fall short of the goal if attention is not given to the equally important maintenance problem.

The objective of the individual residential sewage disposal system is the safe and convenient disposal of household waste, in a manner not hazardous to the health of the family, or to the community, and without nuisance. Under favorable circumstances of design, installation and servicing, the individual residential system is an adequate method of sewage disposal. It is, in fact, a conservation measure in that water, minerals and organic matter are returned to the soil. Under unfavorable circumstances, such systems can be a source of embarrassment and expense to the householder, and a nuisance to the community.

The studies being made by the Environmental Health Center at Cincinnati, under the joint sponsorship of the Housing and Home Finance Agency and the Public Health Service, are directed toward learning the behavior of residential sewage disposal systems under various loading and environmental

circumstances. With such information it should be possible to recommend design standards which are sound, because they are based on facts. Standards so evolved will, of course, result in over-all economies of construction and maintenance.

We think of municipal sewage as the composite of the wastes from a group of individual homes and such industrial plants as may be tributary. Individual household waste, on the other hand, both in quantity and composition, is the result of living habits in one particular home. Consequently, there can be considerable variation among individual cases, depending on the differences in living habits. Therefore, while averages are useful in determining general trends, we must ultimately think in terms of design values which will provide for most, if not all, of the individual cases.

Concerning the quantity of household waste, the guide available to us thus far is the water consumption. Winter water consumption in septic tank-equipped homes ranged from as low as eight gallons per capita per day for some homes, to about 150 gallons per capita per day for others. There is an even greater spread in summer, wherein the range is eight to 226 gallons per capita per day. The average winter water consumption is 39 gallons per capita per day, and the summer 49, in the group of residences we studied.

The character of residential sewage is influenced by home practices in the use of soaps, detergents, garbage grinders, washing machines, and, in some areas, home water softening units.

There are other influences also, as a consequence of which there is a growing tendency to discard the number of persons as a measure of design loading, and substitute for it some other measure of house capacity, such as the number of bedrooms. Initial person occupancy is variable, and is not necessarily indicative of capacity or loading under some subsequent circumstance,

such as change in ownership. Neither is it indicative of additional temporary loads, such as week-end or overnight guests. The number of bedrooms has reasonable stability as a yardstick; is a better measure of the loading potentiality of a home. There is some variability here also, as small homes--say two-bedroom homes, tend to have higher person occupancy per bedroom than do larger homes, such as three and four bedroom homes. Similarly, largest per person water consumption develops in the small home, and tends to decrease as the number of bedrooms per home increases. These are reasons why design size for smaller homes would be larger per unit of loading than for larger homes. The smaller home simply contributes a larger unit loading.

Coming to the Public Health Service studies, it is of interest that five full-size single-compartment residential septic tanks, all of approximately 500 gallons capacity, but of different shapes, including horizontal and vertical cylinders, rectangular and oval shapes, gave essentially equal performance over a year's experimental operation; also, for about the same over-all capacity size, multi-compartment tanks gave higher performance than did single-compartment tanks. Further studies are now under way to determine any advantages of particular multi-compartment arrangements.

It is not to be inferred from this that single compartment tanks will not give reasonably good performance. With good design, ample capacity, and where soil conditions are not too critical, they will operate satisfactorily. However, the importance of ample capacity cannot be overstressed in this connection. In my opinion the undersize tank has done much harm to this type of treatment. It is evident from our experimental studies that 125, 250 and 300 gallon tanks, whether compartmented or not, can operate satisfactorily for but a very short time before becoming overloaded with

sludge, with consequent poor performance. We know too, from study of the accumulations for some two hundred home septic tanks over the country, that larger tanks tend to accumulate more sludge and scum, per person, than smaller tanks. Tanks with capacities of about 125 gallons per person, which would be the equivalent of 500 gallons per four-person family, accumulated scum and sludge at about the average rate for the entire group of tanks examined. Tanks larger than 125 gallons per person accumulated more solids; those smaller than 125 gallons per person, less solids. In other words, the larger tank is more efficient in solids removal.

An increase in capacity is really an economic saving in the long run. For instance, the cost of a single cleaning of a home septic tank ranges from $15.00 to $300.00 in this country. A short time ago, the cost of a 500-gallon concrete tank in Richmond, Virginia, was reported as $55.00, and that of a 750-gallon concrete tank, $65.00. This represents the purchase of 50 per cent additional capacity for $10.00, or about 20 per cent additional cost for the tank. Taking into account the additional excavation, the 50 per cent additional capacity could probably be obtained for about 25 to 30 per cent additional tank cost, installed. More significant, however, is the fact that the 50 per cent extra capacity could stretch the period between cleanings up to roughly two times the original period. Considering the cleaning costs above mentioned, it would not take long to write off the small cost of additional capacity, and enjoy reduced maintenance costs from then on.

I would like, now, to touch briefly on a few design details. As you may know, a minimum liquid depth of four feet for 500-gallon tanks, is commonly recommended in this country. As I mentioned previously, our studies of various basic single-compartment tank shapes, at 500 gallons capacity and water depths approximating four feet indicate that there was no essential difference in

suspended solids removal performance among the various shapes. This opens the door to economic design, using minimum amounts of tank construction materials. For example, economy of construction material could be obtained in shapes approaching a cylinder, or cube, which would amount to a water depth of about four feet, for the 500 gallon size.

We have operated four single-compartment, 500-gallon rectangular tanks on this problem, starting May, 1950, with water depths 28½, 36, 48 and 64 inches, respectively. Two of the tanks, those with water depths of 28½ and 64 inches, are still in operation. In the early phases of this experiment, at low sludge levels, there was no essential difference in suspended solids removal among the four. With start of intermittent sludge additions in September, 1950, performance of all four fell off. The 48-inch tank never recovered, although we have had good performance from similar tanks at this depth. The other three recovered, with performance somewhat in favor of the 64-inch depth tank until about January, 1951, at which time a second period of generally lower and somewhat erratic performance developed, continuing roughly till July, 1951. During this time, and during recovery to date, the 28½-inch tank has shown better performance than the 64-inch tank. The 36-inch tank has since been drafted for another experiment. The 28½- and 64-inch tanks will be continued in operation at least through the spring to observe comparative behavior during rising temperatures at current sludge levels.

Preliminary trials of inlet devices, using uranin dye tracer, indicated that there was no difference in detention behavior of tanks equipped with tee, baffle, or plain unobstructed sewer inlets, but that the tee inlet provided a slightly better flow pattern. Four-inch horizontal slots at

12 inches submergence in the partitions of three-compartment tanks gave detention times about equal to those of a single-compartment tank, but only half the detention time of a three-compartment tank equipped with inverted, vented U-bends as the compartment flow devices. Detention time was lengthened by constricting the slot to a four-inch diameter hole at the same submergence. Further studies of openings at other positions using suspended solids removal as a yardstick will be made. An experimental trial of a tee-outlet, compared with a tank-width weir outlet, indicated no essential difference in suspended solids removal efficiencies.

Concerning servicing of a tank, and I mean by that the physical removal of the solids which have accumulated, it is evident from examination of sludge and scum accumulation data that there is much variation in the rates of accumulation among individual homes of seemingly equal person or bedroom loadings, due no doubt to differences in living habits. If one were to set general intervals for cleaning, based on the more rapid rates of accumulation, such intervals would be sufficiently short to safeguard most of the cases. This would also result in forcing many households into cleaning at intervals of, say three years or less, when they individually could have gone on for some ten years or more, before cleaning were actually necessary, because of their lower rate of accumulation. On the other hand, the setting of cleaning times based on average accumulation rates would result in many failures for high accumulation rate installations. In view of the cost of servicing, the economic answer may be the periodic inspection or gaging, either by the householder, or by an organized service, say at one year intervals, to determine whether tank cleaning is due. We find that a homemade sludge gaging device

consisting of a stick to which is attached a piece of towelling, lowered through the outlet fixture to minimize scum interference, and left in contact about five minutes, will indicate top of sludge level closely enough for practical purposes. As you probably know, you cannot judge the top of sludge by feel. For our experimental and field studies we locate top of sludge by means of a jointed 3/4-inch diameter copper tube which has a watertight plastic window at the bottom, below which is attached a flashlight bulb operated by batteries taped to the open end of the tube. The operator sights through the tube as he lowers it slowly into the tank. The level at which the light blanks out is taken as top of sludge. There is needed a home-made device for measuring of scum since some installations may reach scum storage capacity for a particular design before reaching sludge storage capacity. We use a flat plate hinged to one end of a $\frac{1}{2}$-inch diameter copper tube, through which a wire is used to pull the plate into horizontal measuring position after penetrating the scum. We hope to combine some simple bottom-of scum indicating device with the homemade sludge indicator above mentioned.

As for rates of sludge and scum accumulations developed from analysis of data from tanks in normal operation in the field, the following may be of interest. It appears that the over-all rate of scum and sludge accumulation tends to decrease as time goes on and as digestion and compaction progresses. On a per bedroom basis, the average rates of accumulation for two-bedroom homes are:

Scum: $Y = 0.60 + 0.56X$

Sludge: $Y = 4.50 + X$

Where: Y = Accumulation in cubic feet per bedroom

X = Years in operation since last cleaning

Because of the wide variation among individual cases, the rates of accumulation which would envelop 19 out of 20 cases are of interest. These are, again, for two-bedroom homes:

Scum: $Y = 5.05 + 0.56X$

Sludge: $Y = 12.45 + X$

It may be seen by comparison of accumulations at say three- and six-year intervals, that the values necessary to cover 19 out of 20 cases are roughly two to three times the average. It can be seen from this, as I mentioned before, that the setting of cleaning times on the basis of average accumulation rates would invite difficulties in cases where rates are more than average; and that intervals based on the 19 out of 20 rates would mean that a large number of installations with average or lower rates of accumulation would clean much more frequently than necessary.

Changes in living habits bring up questions of their effect on the sewage disposal system. Current questions concern the effect of ground garbage, detergents, automatic washers and brine waste from regeneration of home water softeners. Briefly, as they concern the septic tank, the following may be of interest.

Ground garbage represents an additional solids load, for which either the storage function of the tank must be expanded to provide for the increased rate of accumulation, or cleanings must be made at more frequent intervals. Preliminary indications from a recent field survey, including installations receiving ground garbage waste, are that there is at least 50 per cent average increase in sludge plus scum accumulations, as compared with tanks not receiving ground garbage in the group examined. In this case it appeared

that the greater part of the increase was in the scum. We expect to do more work on this. On the basis of what information there is, the 50 per cent increase in total tank capacity recommended by the Joint Committee on Rural Sanitation for installations receiving ground garbage appears to be a reasonable precaution. Considering the possibility of installation of appliances, such as garbage grinders, subsequent to installation of the sewage disposal facilities, one might consider taking into account potential increases in loading at the time initial installation is made, and design for them, rather than try to correct for them later. The first owner may have no intention of using various applicances whereas a later occupant may take full advantage of appliances, without knowledge of the limitations of the original sewage disposal facilities. As I mentioned previously, an increase in capacity, whether the tank ever receives garbage or not, is not a loss but an economic saving in the long run.

Concerning detergents, our studies thus far have been largely on their effect on soils absorption, which I will mention later. There is some information from the literature which is of interest. Rudolfs[1] using detergent concentrations up to 100 ppm, found in short period laboratory settling tests, that grease and suspended solids removal efficiencies decreased when detergent concentrations were increased, but that there was no serious disturbance of sludge digestion, aside from possible reduced gas production because of lesser amounts of grease retained. There have been a few informal observations in the field, by others, that sand filters following septic tanks, on restaurant or club installations, tended to clog throughout their depth, instead of at the surface under soap usage.

In a few cases coming to our attention, the use of automatic sequence washing machines tends to change the laundering pattern from the usual Monday to laundering through the week. This may mean sub-capacity loads with full use of water, for some machines at least, with possible additional waste volume to the sewage disposal system.

We made a recent study simulating discharge of brine from water softening regeneration, to a full-size home septic tank. Although salt stratification developed and some bottom layers reached concentrations inhibiting to a normal sludge, no interference with digestion in the septic tank was noted. The principal reasons were the failure of high concentration layers to accumulate in quantities sufficient to envelope the accumulated sludge, which was about 1.2 feet deep, and the tendency for the sludge to become acclimated to the saline environment. The tank purged itself of salt in the spring. This behavior might not necessarily develop in a tank having little sludge accumulation when brine discharges start, such as in a new tank, or a tank returned to service without seeding sludge.

Questions on proprietary compounds purported to "condition," "start" or even "clean" tanks come up frequently. Experiments at Cincinnati, using brewers' yeast, and those previously reported by Heukelekian[2] using bakers' yeast, indicate that yeast has no merit as a "starter." Ripe sludge is of advantage particularly in cold climates. It is probably wise to seed tanks which will receive ground garbage, in that literature on digestion of garbage-sewage mixtures tends to show that an overbalance of sewage solids is desirable. Some of the so-called cleaners on the market contain caustic soda. In an experiment in which caustic soda was added to a full-size home septic tank which had been in normal experimental operation, the pH rose to 12.4 and

remained above 11.0 for about five days; digestion virtually ceased, and the sludge swelled in volume. Had the tank reached solids storage capacity, sludge would probably have been discharged, with consequent damage to soil absorption. A reasonably well-designed and operated septic tank needs no such props. If inadvertent discharge of interfering materials has upset tank action, or if the tank has reached sludge storage capacity, the simplest and safest servicing procedure, considering the protection of the soil absorption system, is to pump out the tank.

Coming to the soil studies, it is of interest to consider the tremendous amounts of liquid being applied to an absorption system as compared to what soils normally absorb from rainfall or from irrigation. Average rainfall in this country ranges from 30 to 50 inches a year, with extremes up to 150 inches. Allowing for evaporation and runoff, the soil absorbs some 20 to 40 inches, with a maximum of possibly 100 inches. In irrigation, the maximum amounts of water applied annually is about 100 inches. Current home absorption field design practices, however, permit some 200 to 1,100 inches annually, with extreme cases found in the field amounting to over 2,000 inches annually. It is evident then that the quantity of liquid imposed on the soil is in itself a major factor, to which is added the complicating influence of sewage constituents.

The design of a soil absorption system involves factors such as the clogging characteristics of the septic tank effluent, the volume of waste to be disposed of, the climate of the area, and most important, the absorption characteristics of the particular soil being considered. A basic soil problem is the estimation of the absorption characteristics of a particular soil by test, a topic studied for years in agriculture and still not satisfactorily

solved. There are methods and aids for estimating soil water absorption characteristics which are of some help. Soil information for many areas is published by the U. S. Department of Agriculture, in the form of soil maps and soil descriptions, which are of help. Another aid is the close visual inspection of the soil on site, the main clues being soil texture, structure and color.

Soil texture, which means the proportion of sand, silt and clay, is a common clue to permeability, as particle size governs pore size, which in turn influences the rate of water movement. Texture, as a yardstick, has limitations, and is reliable only in sandy soils. In heavier soils containing appreciable amounts of silt or clay the soils structure becomes an important additional clue.

Soil structure results from the tendency for individual textural particles, particularly clay particles, to clump together to form secondary particles of larger size. These tend to govern size and distribution of pore space, and in turn, the absorption properties, rather than the individual textural particles. With well-developed structure a lump of soil will break apart, with little force, along well-defined cleavage planes into uniform sized and shaped units. With no structure, more force is required, and the lump will break along irregular surfaces.

Color is one of the most important visual clues to soil permeability. Bright uniform, reddish-brown to yellow colors throughout a soil profile indicate favorable oxidation conditions, and ultimate movement of air and water, promoted by desirable moisture absorption properties. Soils which are light gray in the topsoil and dull, drab and mottled in the subsoil, indicate lack of oxidation, very restricted movement of air and water and are likely to be less permeable.

Although the clues above mentioned are of value, they do not obviate the necessity of a quantitative test of water absorption rates. The percolation test proposed by Ryon[3], together with his development of an empirical relationship between the clear water rate and the rate at which septic tank effluent might be applied successfully, is the basis of most of the design recommendations used by various control agencies today. The Ryon test involves the digging of a one-foot square hole to anticipated trench bottom, the saturation of the hole by filling with water and letting it seep away, followed by refilling to about six inches, and measurement of the time required for the water level to drop one inch. With this information, tables developed from Ryon's empirical relationship are used to arrive at the necessary trench bottom area, per unit of house loading, such as per bedroom.

We have examined the Ryon test experimentally, as a consequence of which we suggest modifications which we believe to be improvements. Briefly, these are: (1) the substitution of a 4-inch bored hole for the laborious 12-inch square dug hole; (2) the more complete saturation of the soil; and (3) the use of the minimum observed rate instead of the average or some initial rate. Comparative tests of 4-inch and 8-inch auger holes, and a one-foot square dug hole, in soils representing a wide range in percolation rates, have indicated that there is no significant difference in the rates among the three sizes of hole tested. A saving in labor, and in the amount of water used, develops with the bored hole. The saving in labor per hole can be invested profitably in replicating tests in an area. Due to soil variability, a single test is often useless in estimating absorption characteristics of areas as small as 100 foot square. Six tests, sometimes more, are needed in such an area to obtain a reliable estimate. The saving in water per hole

becomes of significance in tests over undeveloped tracts of land, where water for testing purposes must be carried in. In securing more complete saturation before testing, opportunity is given for swelling of the soil. This is particularly important in clay soils. The use of the minimum rate, rather than the average or some initial rate is undoubtedly more representative of soil percolation behavior under conditions of actual use.

The use of existing design tables in conjunction with the slower percolation rates obtained many times by the modified tests will result in larger absorption areas than those based on the older test procedures. This is probably on the safe side. However, it is possible that under current habits of home living, sewage characteristics may be somewhat different than those upon which Ryon's work was based. There is, consequently, need for redevelopment of empirical relationships between successfully operating systems in a variety of soils, and the more refined test results. This entails considerable field study which we cannot undertake at this time, but we hope to do some work on it next year.

Experimental studies of some of the physical, biological and chemical factors contributing to soil absorption behavior under effluent loadings are being made. Physical clogging is simply the plugging of soil pores by solids. Biological clogging, common in agricultural water spreading work results there from plugging of pores by biological bodies and by-products, or from destruction of soil structure by biologic activity. In the application of septic tank effluent to soil it appears from our preliminary studies that biologic activity does not cause clogging, but instead, tends to reduce the clogging tendency of other factors. Chemical clogging is also a common agricultural soil problem in the West, particularly where irrigation is practiced. "Black alkali"

soils developing in some areas result from irrigation with waters high in sodium. It is considered that waters in which 50 per cent or more of the cations (sodium, potassium, calcium and magnesium), is sodium, are harmful to water absorption characteristics of a soil.

In our experimental study of the effluent sodium clogging influence, the relative amount of sodium to calcium was modified by adding gypsum to the effluent. It was found from core dosing studies that soils having a well-developed structure tended to maintain the structure and clog less under the calcium fortified effluent dosage than with normal effluent dosage. In single grained soils, with no apparent structure, there was no difference in the rate of clogging between the fortified and normal effluent dosed cores. As mentioned previously, some proprietary septic tank "cleaning" compounds contain caustic soda. Soil cores dosed with effluents to which caustic soda had been added, in concentrations well below those expected from a typical "cleaning" dose, caused immediate clogging and accompanying damage to soil structure. Similar, although less dramatic, results were demonstrated using potassium hydroxide. Sodium hydroxide is indeed used as a dispersing agent in soil textural analysis to destroy structure and reduce the sample to its textural elements. When so dispersed soil becomes an impermeable mass.

There is laboratory evidence that septic tanks receiving ground garbage will require larger absorption fields. In the laboratory, soil cores, ranging from silty clay to rather heavy clay, were dosed with effluents from tanks receiving ground garbage and sewage, and sewage only, as a control. Cores receiving the garbage-sewage effluent clogged more rapidly than those receiving the sewage effluent, both on a time, and solids-for-solids basis. The additional soil area required for the garbage-sewage effluent treated cores,

to equalize the clogging rates, would be roughly 25 to 35 per cent. Recent examination of systems in the field indicates that there is more organic matter in soil samples for systems receiving ground garbage than in those not receiving garbage. Further information will become available on this when the analysis is complete. In my opinion an increase of 50 per cent in design absorption field size would be a reasonable precaution against failure due to inclusion of ground garbage.

Concerning the effect of household detergent use, on soil absorption systems, studies in which detergent and soap respectively were added to tank effluents, indicated no differences in clogging tendencies other than those associated with differences in the amount of suspended solids. Similar studies using tap water suspensions of grease and soap, and grease and detergent did show differential clogging. There was immediate tendency for the soap-grease suspensions to cause greater clogging than the detergent-grease suspensions. Increasing quantities of grease in the soap suspensions caused slight increases in clogging, but the quantities of grease in the detergent suspension showed no apparent correlation with clogging. Recent experiments in which wash waters from a home washer, using soap one week and detergent the next, were applied to laboratory soil cores, indicated no differences in clogging rates on either a time, or solids-for-solids basis.

Dosage of soil cores with effluent from a tank receiving sewage and brine waste from simulated softener regeneration indicated no short time damage to percolation rates as compared with normal effluent, but there was some damage to soil structure, which may be important from a long time viewpoint. Field examinations are to be undertaken on this later.

In closing, I should like to emphasize a few thoughts which should be kept in mind in dealing with household "septic tank systems." The first is that the septic tank is not a disposal system of itself, but is an important unit of a process in which the objective is the disposal of a large amount of waste liquid, mostly into the soil. Soil, for waste disposal purposes, is a sensitive medium, not only sensitive to the heavy liquid loadings usually placed on it, but susceptible also to damage from abnormal changes in the waste being applied to it. We should keep this in mind, not only in considering septic tank design and operating factors, but also in connection with servicing procedures. The second thought is that while the development of factual information is of fundamental importance, it will fall short of its purpose if it is not applied effectively in the field; that is, incorporated into the design, installation, operation and servicing of each individual installation.

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